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elytes, or to enjoy any other than a temporary notoriety. It has been received, as we have seen, with but little favor in France, and Miss Martineau's efforts are not likely to obtain for it much currency in England. Even the controversy which it has evoked cannot much retard its progress to oblivion.

Art. X. — *Annual of Scientific Discovery: or, Year-Book of Facts in Science and Art, for* 1854. *Exhibiting the most important Discoveries and Improvements in Mechanics, Useful Arts, Natural Philosophy, Chemistry, Astronomy, Meteorology, Zoölogy, Botany, Mineralogy, Geology, Geography, Antiquities, &c.; together with a List of recent Scientific Publications; A Classified List of Patents; Obituaries of Eminent Scientific Men; Notes on the Progress of Science during the Year* 1853, *etc.* Edited by David A. Wells, A. M. Boston: Gould & Lincoln. 1854. 12mo. pp. 398.

Few or none of the centuries prior to the eighteenth could have furnished for a book like this so copious materials as are now afforded in the lapse of a single year. The last year, indeed, was marked by no one world-famous invention or discovery; but it gave birth to unnumbered new applications of known principles and new corollaries from established premises. In earlier times science and art respectively characterized not the same, but successive ages. The great men of one epoch wrought from within outward in enlarged generalizations, annexing new provinces to the domain of knowledge, or arrested for analysis laws or agencies of the material universe which had eluded previous research. Their successors for more than one generation were then employed in colonizing the newly annexed territory by contrivances of practical utility, and in giving concrete shape to abstract formulæ. Indeed, the two processes belong to widely different classes of minds, which demand very unlike influences for their development, and which (whether contemporaneously or otherwise) coöperate as the stamens and pistils of a plant do in elaborating the seed. The scientific mind is fertilizing, but not fruit-bearing. Its cognizance is of powers and properties, not of uses and adaptations. It can expound, but cannot apply. But there is another description of men, incapable of profound scientific views, who yet have an affluence of mechanical resource and skill, and are perpetually on the watch for hints which they can make the basis of experiment. To the former class belongs, no doubt, in strict justice, the paternity of whatever inventions are perfected by the latter; but, as the child follows the mother's fortunes, it is almost always practical skill, — the genius of manipulation, — that gives its name to the embodied principle, wears the laurels, and reaps the emolument. Whatever may have been the causes that were wont to create a dearth in artistical during the ascendency of scientific genius, and *vice versa*, they have now ceased to operate, and in our day principles are put to use as fast as they are verified, — natural laws are made availing for the economy of life as soon as they are discovered, — broader generalizations pass simultaneously through the printing-press and the machine-shop.

There is, therefore, a peculiar timeliness in a work like the one before us, which comprises the transactions equally of the Association for the Promotion of Science and of the Patent-Office, the theory of lunar volcanoes and the last refinement in friction-matches, polarization and photography, improvements in reflecting telescopes and labor-saving compositions for the laundry. The volume thus records the year's onward march of civilized man in the investigation and appropriation of the material universe, — in the knowledge which alone can establish his lordship over nature, and in the individual acts of sovereignty which cause that lordship to be owned and felt.

We propose in this paper to offer a few illustrations of the dependence of art on the exact sciences, that is, on mathematics, or the science of number, magnitude, and quantity. Inventions are indeed commonly regarded as happy guesses, and they often are so to the consciousness of the individual discoverer. They are indeed frequently the result of merely fortuitous circumstances, without intention or forethought, the so-called inventor being only the passive witness of an issue of his experiment widely different from his aim and expectation. But in every such case, the invention needs scientific handling, measuring, testing, and tempering, before it can be employed with certainty of success, or adjusted to the variable elements of size, material, location, and quality of result. More commonly, however, the happy guess is struck out by a mind practically cognizant of the scientific truth which it embodies, or even simultaneously by several minds in a department, the scientific bearings of which have recently become public property; and then only does it leap from the inventor's brain fully formed, and prepared for immediate service.

It is impossible to determine by historical data the relative antiquity of science and art; but we have satisfactory evidence that geometry and astronomy were successfully cultivated long before the Homeric age, and contemporaneously with, if not prior to, the earliest forms of civilization that have left any record or vestige. Nor yet can we go back to an age in which the fundamental laws of number and proportion were not understood, though until the decimal notation came into use arithmetical problems were solved with the utmost slowness and difficulty. These sciences were indeed nominally confined to the little circle of the initiated; for the diffusion of knowledge as such is not only a Christian idea, but one of the latest corollaries of Christianity. But knowledge transpires without being laboriously propagated. Processes of reasoning and investigation may indeed keep the secluded route of scholastic transmission; but established truths, so soon as they take their place as undisputed axioms, are popularized, and enter into the working capital of the general mind. Geometrical proportions must have had their architectural expression, almost as soon as they were eliminated. Astronomical laws, when first ascertained, must have speedily worked their way into navigation, and without their guidance Phœnician enterprise would never have tempted the perils of the deep, or colonized barbarian coasts. The mechanical powers depended for their earliest successful working on some dim perception of the principles that underlie and govern them, though ages may have elapsed before their formulæ were written out with entire precision. The bee, the ant, the coral insect, and the beaver, anticipated indeed the highest results of science; for *Deus est anima brutorum*, — their structures indicate the Supreme Architect working in and through them. But man has no instinct which precedes or can supersede knowledge; and what we call *native* mechanical skill is merely the capacity of studying mathematical principles in their existing embodiments, — of substituting buildings for books, — of taking in scientific truth by the organs of sense rather than by the reasoning faculty. We may then, in the absence of all proof to the contrary, assume that science from the first held the torch to art, and presided over the earliest steps of material civilization.

Of this view we are rendered the more confident by the perfectness which the exact sciences had attained at very early epochs of authentic history. It is impossible to overestimate the mathematical knowledge of Pythagoras. It requires no great latitude of interpretation or license of fancy to suppose that he stood upon the confines of the continent of truth, laid open to the world by the successive labors of Copernicus, Kepler, and Newton, and that he was prevented from taking possession of it only by the lack of those keener instruments of analysis comprehended under the generic name of algebra. In the absence of an adequate language of signs, his processes of investigation necessarily perished with him; but at the present day it would be hardly possible without a scientific vocabulary to enunciate the profoundest truths of modern cosmical science more explicitly than they seem to be indicated in some of the writings of his school. However this may be, there can be no doubt that he was deeply versed in geometry, and especially in the properties of the triangle, to which the rules of the arts of design and construction may almost all be referred. But the universal tradition was, that he derived the rudiments of his knowledge from Egypt, so that, as Egyptian monuments also give us ample assurance, science was old when Greece was young. Now Pythagoras flourished several generations before the Periclean age, — the culminating era of Grecian art; nor do we know aught of its earlier history which authorizes the belief that it was at any period in advance of science.

Euclid lived at an epoch about as long subsequent to the Periclean age as the lifetime of Pythagoras preceded it; and from him geometry received substantially the form in which its propositions are taught and learned at the present day. *Substantially*, we say; for his translators have perfected much that was faulty in his arrangement, have supplied many of the steps of demonstration which he omitted, and have given greater precision to terms which he employed, sometimes in a popular and sometimes in a technical signification. But the original structure of his "Elements" indicates even more fully than the modern editions his intimate familiarity with the entire ground; for his omissions are generally of those intermediate portions of a statement or proof, on which the mind of a thoroughly trained mathematician would not pause, but of which a tyro would take distinct and emphatic cognizance. These omissions also have an important bearing, as betokening the receptivity of those for whom he wrote. In fine, his works presuppose for his age no mean standard of attainment in mathematical science.

Archimedes, a century later, developed the geometry of conic sections and of the solids generated by them, as far as was possible without the aid of the Differential Calculus. He led the way, also, in the artistical application of his own principles, and as a practical mechanician and engineer might be brought into favorable comparison with the Arkwrights, Fultons, and Stevensons of modern times. The influence of his mechanico-mathematical researches may be distinctly traced in improved modes of fortification and assault, in massive public works, the vestiges of which are still extant, and in all those utilitarian aspects in which alone Roman surpassed Grecian art.

We have not mentioned India, and have made only cursory reference to Egypt, in this connection; for the vagueness of chronological data with reference to these early seats of a high material civilization leaves us in doubt as to the relative precedence of the sciences in which we know their people to have been adepts, and the arts which have made for themselves a bridge across the gulf of uncounted centuries, and present themselves almost in pristine freshness and perfectness to the research of the generation now living. But through the entire period of modern history, art has never been to any considerable degree merely tentative or spontaneous, but has always followed in the wake of science; and each age has elaborated only such inventions or improvements as had been tacitly predicted by the enlarged knowledge or the more adequate theories of preceding generations. And in our own day the seeming simultaneousness of scientific and artistical progress resolves itself into antecedence and sequence with abbreviated intervals; for facility of communication and universal activity of mind now perform the work of lengthened time, as by the forced cultivation of the hot-house, ripening science into art with preternatural rapidity.

But, even were not our position capable of being approximately verified in history, it would be none the less certain that all high, enduring, and permanently useful art is, in its nature and essence, mathematical, that is, underlaid and governed by mathematical laws, whether those laws were at first intuitively perceived, ascertained by experience, or reduced to scientific expression. This is sufficiently obvious with regard to architecture* and mechanical operations of every sort, which depend on definite proportions and relations, the violation of which could be atoned for by no exuberance of beauty or misplaced accumulation of strength, but would issue in waste and ruin. Equally do such maritime expeditions as those of Nearchus and Hanno imply an actual knowledge, however obtained, of laws embracing the entire solar system, and extending to the stars, whose distance eludes calculation, yet which were even more essential, before the polarity of the needle was discovered, than now, as finger-posts and milestones on the waste of waters. Similar statements apply to many of the inferior arts, and to numerous mechanical processes which may be conducted by men who know not their multiplication-table. Had not observation identified or science marshalled into order numerous spaces and proportions, earthly and celestial, our race must have remained at a very low point of civilization;—men would have dared to rear only structures safe from their insignificance or their superfluous and ungainly massiveness;—no machine or mechanical force beyond a rude knife or mallet would have helped the labor of the hand;—hollowed trunks of trees or bark canoes would have continued timidly to skirt the sea-coast, without venturing beyond sight of the shore.

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* The dependence of architecture on accurate mathematical knowledge seems to have been as distinctly recognized by the ancients as it is at the present day. Vitruvius says that the architect must be "*eruditus geometria, optices non ignarus instructus arithmetica.*"

The fine arts, no less than those which minister to humbler uses, are rigidly governed by mathematical laws. "The vision and the faculty divine" may indeed apprehend these laws intuitively, and work out the results, while ignorant of the processes of science; but even the highest genius must often pay the penalty of ignorance by gross errors of detail, and must yield to better cultivated mediocrity in point of those negative merits which chiefly claim the cognizance of unimpassioned critics.

Music is a science of numbers, and has owed its development hardly less to Newton, Lagrange, and Euler, than to Mozart, Beethoven, and Rossini. The theory of the flute-note finds its place in the Principia with the harmony of the spheres. The relative magnitude of the pipes of an organ, the duration of their vibrations respectively, and the quality of the resulting tones, constitute a series of numerical proportions not less definite and uniform than those which govern the planetary orbits. The sole reason why reed-instruments and reed-pipes are less manageable than other instruments of music is, that they involve complex problems which still lack a complete mathematical solution, so that only empirical, and not exact rules, can be laid down for their construction. Musical intervals are rightly designated by arithmetical names; for they may be represented with no less definiteness by figures than by notes, and indeed the former mode has gained general currency as regards the instrumental bass.

Nearly allied to music is the entire subject of practical acoustics, as to which there are few determinate rules of art, simply because the science which should furnish them is still in its infancy. It is, as we well know, a question involved in utter obscurity, and to be answered only by trial, whether a hall or a music-room in the process of construction shall reflect the waves of sound symmetrically or confusedly, with a gentle rebound or with a deafening echo. Here even experience is at fault; for it is almost impossible to repeat a successful experiment in all the details of materials, dimensions, and arrangement, and there is always a strong probability that the seemingly unessential point of deviation will vindicate its importance by the failure of the trial. It must then be ultimately by the embodiment of profound and recondite principles of science, that the most queenly of the arts can command a throne worthy of her sceptre, or an audience-hall fit for her mission.

Mathematical principles equally underlie the arts of design. Colors have their mathematical no less than their chemical laws, and, as separated by the prism or as recombined in art, indicate mutual relations which can be expressed only in abstract formulæ. All delineation worthy of the name — whether it be of actual objects of sight or of ideal objects to which the imagination gives an actual *situs* — corresponds to one or another mode of mathematical projection. True, there is often no consciousness of this; but the eye of the born artist geometrizes by right of nature, apprehends focal distances intuitively, and has the laws of perspective inscribed on its retina. The picture, however gorgeously colored, which is mathematically false, at once disappoints and displeases. A phototype of the human countenance seldom satisfies, and this for two mathematical reasons. First, the focal distance of the camera is too short with reference to the elevation and depression of the different features, so that the fidelity of the image is in inverse proportion to the prominence of the features; and, secondly, only a hemisphere of the human head can be projected upon the daguerrean plate, while more than a hemisphere is seen by the two eyes of the living observer. This last defect is remedied by the stereoscope, which simulates binocular vision, either by means of mirrors blending two pictures in one statuesque image to be beheld by the single eye, or by placing the two pictures at such a distance that, as seen by both eyes, they shall be blended in one image. But may not the application of mathematical laws to the daguerreotype be yet made the means of giving to the pictorial art an accuracy hitherto unrealized? No countenance or object can be detained by the painter for so microscopically minute a delineation as the sun burns into the plate. Why may not the daguerreotype be as it were translated, the correcting formula be applied to its several portions, and thus the image which would be painted on the living retina deduced from that on the metallic surface? Find fault as we may with the sun as an artist, we believe that, by some such process as this, portraiture especially is to attain a fidelity and a lifelikeness closer beyond all comparison than are usually reached by the sittings in the painter's *atelier*.

But in these matters we confess ourselves of the laity, and know not but that on the one hand we may have been propounding what are truisms among the initiated, or on the other parading our ignorance, rather than our philosophy, of art. But however this may be, our sole object in these few and desultory remarks, suggested by the Year-Book, has been to substantiate and illustrate the proposition, that all art is essentially mathematical in its fundamental principles and in the reasons for its rules.

Mathematical science is literally a portion of the Divine intelligence, — not our faint approximation to it, or our distorted version of it, but an unperverted transcript of it. In mathematical relations, laws, and proportions, and probably in these alone, we see precisely as God sees, — we attain absolute and necessary truth, — we have glimpses of the actual plan of the universe, — we handle the compasses with which the Almighty meted out the borders of the earth and described the stellar orbits. In metaphysical and moral science, we gain only relative or proximate truth, our views alter as they grow, and with every accession of knowledge or enlarged comprehensiveness of conception there is need of correcting numerous errors that had attached themselves to lower stages of attainment. But in mathematics no increase of knowledge stales or modifies what we previously knew. The first law of numbers, the first geometrical theorem which the child learns, remains for ever unchanged to his apprehension, though he may reach the stature of a Newton or a Bowditch. Here then is the loftiest dignity of art. It is the embodiment of absolute truth, — the circumscription in material forms of principles that are universal and eternal, — the transcript by human hands of the thoughts of God. Its rules could have been devised, codified, and applied only by minds, which at this point could enter into direct communion with the Supreme Intelligence, — which could in this regard occupy the Divine point of view, — which could comprehend the very relations and proportions that dwelt from all eternity in the Infinite Spirit, and were crystallized by his fiat in suns, worlds, and systems. Here most assuredly we reach the climax of "the inspiration of the Almighty that giveth man understanding." Let then the anthem of toil, and skill, and handicraft, go up to the Creator. Let man, the maker, the artificer, the builder, praise him. Let thoughts of worship run through the crowded haunts in which

"The busy heart of universal man
Seems throbbing ever without pause or plan."

For in this view the "incorruptible Spirit that is in all things" is no less vitally and demonstrably present in the massive and sky-reaching structures of human skill and might, in the world-subduing energies of culminating art, in the thronged mart of industry and traffic, than in the silent mountain, the primeval forest, the multitudinous roar or the "many-twinkling smile of the ocean waves."